PERMANENT MARKS LEFT BY WORK AND THE WAY OF LIFE ON HORSES' METATARSUS BONES - DETERMINING THE USE OF HORSES IN ARCHAEOLOGY USING AN OSTEOMETRIC METHOD•

A MUNKAVÉGZÉS ÉS AZ ÉLETMÓD MARADANDÓ NYOMA LOVAK LÁBKÖZÉPCSONTJÁN - RÉGÉSZETI KORÚ LOVAK HASZNÁLATI MÓDJÁNAK MEGHATÁROZÁSA OSTEOMETRIAI MÓDSZERREL

BOZI, Róbert[1] & SZABÓ, Géza[2]

[1]Ars Med Vet Clinic, H-6200 Kiskőrös Jókai street 5.

[2]Wosinsky Mór Museum, H-7100 Szekszárd, Szent István square, 26.

E-mail: boziaodr@gmail.com

Abstract

In archaeology material finds related to horses are always given special attention. In spite of this, the examination of the manner in which horses were used, in most of the cases, is limited to the evaluation of observations made at the excavations, the attachments, and maybe the abrasion marks visible on the bones. Up to now we could use only the harnesses found near the skeletons, or possibly the remains of carts to develop an idea about how and for what purpose people could have used this animal in specific cases that was especially important for people for feeding and working and from the economic and social aspect. In lack of attachments, however, we could hardly say anything about the horse skeletons we found, apart from the general data (sizes, age, etc.). Despite the fact that the structural differences have been detected earlier in the bones of horses carrying out different work, research that is explicitly targeted at this topic has not been conducted up to now. In examining two archaeological finds, we were compelled to answer the question raised: is it possible to determine the type of work the horses carried out based on the bones found in excavations? The key to the comparative analyses was the examination of the structure of the metatarsus by a practicing veterinarian of 64 horses of different life history -from prehistoric wild horse species representing the natural state, and domesticated specimen not performing work, mounts and draught horses - by using the method he developed. He found consistent differences between the structure of the metatarsus of individual members of the groups with differing life history. Based on the metatarsus structure we are able to tell with a high level of certainty (80-85%) the manner in which the specific horse worked, its leg position type, its age group, or pregnancy. He managed to work out such an osteometric basic method, filling a gap on the international level that is suitable to establish- independently from attachments - the way horses of archaeological age were used. In addition to archaeological finds, the new method can be used to examine horses, to solve potentially arising judicial issues, to explore the manner of use, to analyse environmental impacts and to observe the dynamics of the population.

In the archaeological examples presented the test results of samples analysed by using the described osteometric basic method in both cases significantly contributed to the clarification of the archaeological-historic connections. The case of the horse of Dombóvár is especially enlightening, which, based on the traditional evaluation of archaeological observations, thought so far to be a pet buried with its master. The measurable results of the osteometric tests, however, called attention to the appearance of the habits of a foreign population in the late Roman period, putting the observations of earlier excavations into a new historic context. Also, in the case of the Csontos-szurdik we managed to determine the age and nature of the site even without an archaeological excavation. These two cases well reflect that the osteometric basic method demonstrated for the examination of the metatarsus of horses may be an important and useful supplement in archaeological research. The recent results clearly indicate that it would be worthwhile and efficient to repeat the examination and evaluation of such old and well-known finds as, for instance, the horses of the Kurgans of Arzhan and Pazyryk, or the horses in our tombs from the time of the conquest of our homeland.

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Kivonat

A régészeti anyagban a lovakkal kapcsolatos leleteket mindig megkülönböztetett figyelem kíséri. Ennek ellenére a lovak használati módjának vizsgálata legtöbb esetben kimerül az ásatási megfigyelések, a mellékletek, esetleg a csontokon látható kopásnyomok értékelésében. Csak a csontvázak környezetében talált lószerszámok, esetleg kocsi maradványai alapján alkothattunk eddig képet arról, mire és hogyan is használhatták ezt az ember számára a táplálkozás, munkavégzés, gazdasági és társadalmi szempontból is különösen fontos állatot a konkrét esetben. Mellékletek híján pedig az általános adatokon túl (méretek, életkor, stb.) végképp alig tudtunk valamit mondani az előkerülő ló csontvázakról. Annak ellenére, hogy a különböző munkát végző lovaknál már korábban észlelték a csont szerkezeti különbségeit, kifejezetten ilyen irányú kutatások eddig nem folytak. Két régészeti lelet vizsgálata során kényszerítő módon merült fel a kérdés: vajon a feltárások során előkerült csontok alapján meg lehet-e határozni a lovak munkavégzésének jellegét? Az összehasonlító vizsgálatok megoldó kulcsát az adta, hogy a gyakorló állatorvos 64 különböző élettörténetű, a természetes fajtól, valamint háziasított munkát nem végzett-, hátas- és fogat lótól származó lábközépcsont szerkezetét vizsgálta meg az általa kidolgozott módszerrel. Következetesen meglévő különbséget talált a más-más élettörténetű csoportok egyedeitől származó lábközépcsontok szerkezete között. A metatarsus szerkezete alapján nagy biztonsággal (80-85%) képesek vagyunk megmondani az egyed munkavégzésének módját, lábállásának típusát, korcsoportját, a vemheséget. Sikerült egy olyan, nemzetközi szinten is hiányzó oszteometriai alapmódszert kidolgozni, amely alkalmas a régészeti korú lovak használati módjának meghatározására a mellékletektől függetlenül. Az új módszer a régészeti leleteken túlmenően alkalmazható lovak vizsgálatára, az estlegesen felmerülő igazságügyi kérdések megoldására, a használati mód feltárására, a környezeti hatások elemzésére, populáció dinamikai megfigyelésekre is.

A bemutatott régészeti példákban az ismertetett oszteometriai alapmódszerrel elemzett minták vizsgálati eredményei mindkét esetben jelentősen hozzájárultak a régészeti-történeti összefüggések pontosításához. Különösen tanulságos a dombóvári ló esete, amely a régészeti megfigyelések hagyományos értékelése alapján eddig a gazdájával eltemetett házi kedvencnek tűnt. Az oszteometriai vizsgálatok mérhető eredményei azonban a korábbi ásatási megfigyeléseket is új, történeti összefüggésbe helyezve egy idegen népesség szokásrendszere késő római kori megjelenésére hívták fel a figyelmet. A Csontos-szurdik esetében pedig a régészeti feltárás hiánya mellett is sikerült meghatározni a lelőhely korát és jellegét is. Ez a két eset is jól mutatja, hogy a lovak lábközépcsontja vizsgálatára bemutatott oszteometriai alapmódszer fontos és hasznos kiegészítője lehet a régészeti kutatásoknak. A mostani eredmények egyértelműen jelzik, hogy érdemes és eredményes lenne olyan régi ismert leleteket is újra vizsgálni és értékelni, mint például az arzsani, paziriki kurgánok, vagy a mi honfoglalás kori sírjaink lovai.

KEYWORDS: HORSE, WAY OF LIFE, WORK, METATARSUS, OSTEOMETRICS, METHODOLOGY, ARCHEOZOOLOGY

KULCSSZAVAK: LÓ, ÉLETMÓD, MUNKAVÉGZÉS, LÁBKÖZÉPCSONT, OSZTEOMETRIA, MÓDSZERTAN, ARCHEOZOOLÓGIA

In recent years on several occasions we excavated such horse skeletons that in some respects differed from the general archaeological phenomena of the specific age. In the excavation preceding the building of the Tesco supermarket in Dombóvár, somewhat further away from the cemetery section from the Roman period, there were two distinct burials, also differing in their orientation. In grave DTQ83, the skeleton of a horse and a dog were lying (**Fig. 1.**), it was just obvious to relate it to the similarly oriented late Roman brick tomb located nearby, at a distance of 2.5 m (DTQ84, **Fig. 2.**) and to date it to the same period based on the ~~finds~~ in the tomb (Boruzs 2007, 87-89; Boruzs & Szabó 2018, 206). Based on the archaeological observations and archaeozoological examinations it was most likely the resting place of a warrior or hunter with his riding horse buried close to him saddled and harnessed and his dog lain at the hind legs of the horse (Boruzs 2013; Daróczi-Szabó & Bartosiewicz 2018). In Mágocs, lying on the opposite side of the river Kapos, burials were observed - similar to some unusual but not unique in the Roman period - where the skeleton of a horse was excavated also near the brick tomb from the late Roman period placed in the same direction. In the graveyard in Mágocs no such phenomenon could be observed that would have suggested a reason why the horse was buried, but looking at the belt buckle found in one of the graves of a woman research contemplated the appearance of a custom definitely pointing to a newly arrived ethnic group (Gábor 1998, 113., 116).

At the northern boundary of Szekszárd, in the side of the Csontos-szurdik, a baffling quantity of anatomically connected remains of horses thrown over one another in a length of almost twenty metres can be seen, among them one or two human bones and those of smaller animals (**Fig. 3.**).

Fig. 1.: DTQ83. horse tomb found in late Roman-period site at Dombóvár-Tesco
1. ábra: Dombóvár-Tesco késő római kori lelőhelyen feltárt DTQ83. ló sír

Fig. 2.: DTQ84. brick tomb in the direct proximity of the buried horse
2. ábra: DTQ84. téglasír az eltemetett ló közvetlen közelében

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Fig. 3.: Bone deposit located in the embankment of Csontos-szurdik, Szekszárd

3. ábra: Szekszárd, a Csontos-szurdik partoldalában húzódó csontréteg

It was difficult to establish the age and function of the bone layer as we did not know an archaeological find from the location that could date those and we were not familiar with a similar phenomenon in other parts of the Carpathian basin either (Bozi & Szabó 2017). According to local folk traditions, the embankment commemorates a battle from the Ottoman period, while others think that the place was used as a carcass pit during the great horse sickness epizootiology in the 18th century (Kovách 1922, 2). The human bones contradicted the concepts regarding the modern-age carcass pit, while the lack of archaeological finds and the bones of smaller animals were contrary to the ideas about a mass grave of a battle fought in the Middle Ages. In spite of having been a known location threatened by development, it was not included even among the registered archaeological sites at the time of our examinations in 2017 (Szabó 2017, 1579). To answer the fundamental question, i.e. its age, in the framework of scientific cooperation, Isotoptech Zrt. in its Debrecen laboratory performed the radiocarbon dating of the bone samples from the Csontos-szurdik. According to the results of the AMS ^{14}C tests, the bone layer in the embankment is 1353 ± 24 (BP, ±1σ) old, which means that it is to be clearly regarded as an archaeological site. Based on the calibrated data it can be stated with 93.9% probability that the animals could have been buried between 641–690, i.e. mostly at the start of the second phase of the Avar period (Ramsey 2019, OxCal4.3) (**Fig. 4.**).

At the above-mentioned location in Dombóvár indirect data suggested the manner in which the buried horse was used, but the archaeological observations of the horse excavated in the burial place of the nearby Mágocs under similar circumstances, for instance, did not confirm these assumptions. Furthermore, at the Csontos-szurdik we had no clue whatsoever to determine how these horses were used and why they were buried.

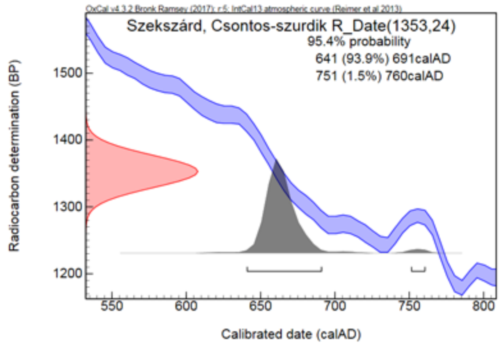

Fig. 4.: Calibrated AMS radiocarbon date of a bone sample from Csontos-szurdik, Szekszárd (Isotoptech Zrt., DeA-11508; Ramsey 2019, OxCal 4.3)

4. ábra: Szekszárd, Csontos-szurdikból származó csontminta kalibrált AMS radiokarbon adatai (Isotoptech Zrt., DeA-11508; Ramsey 2019, OxCal 4.3)

This called our attention that such a method would be necessary that could be used to gain basic information in an exact manner about the life story of the horses found in the archaeological sites – even in the lack of indirect data - or for the clarification and control of the existing finds. We wanted to use osteometric methods to find out how the riding horse buried in the tomb DTQ83 in Dombóvár was used and for what, and whether the horses buried at the Csontos-szurdik were killed in battle indeed.

Lasting marks of work and the way of life on horses' metatarsus

Almost always special attention is paid to the remains of horses among animal bones appearing in excavations in large quantities, and the need arises to find out as much as possible about the life history of the animals. We primarily have indirect evidence for that, partly objects turning up in relation with the partial or complete skeleton, for instance, the parts of the harness (bit, saddle, cart, stirrup, embossing on tools etc.), or external appearances apparent on the bones, including spondylosis, chronic inflammatory alterations in various joints of the limbs, arthritis and exostosis, osteophyta apparent on many bones. The bones, often turning up from waste pits, or found isolated among archaeological phenomena, hardly carry any indirect evidence.

The life history of an animal leaves a lasting impression on its solid frame. By life history we mean health-disease, everyday struggle for survival in natural or artificial environments, giving life to offspring(s), and permanent behaviour or patterns of movement, natural or deviations from that. The alterations visible on the bones are mainly the preserved traces of health-disease. The special morphological characteristics evolving based on the metabolic mechanisms and biomechanic properties of the living organism have a causal relationship with the lifestyle, the constitution, the manner, intensity and duration of work, and in the case of females, with reproduction. These morphological characteristics may be identified through the observation of the structure of the bones.

The locomotion movement of horses starts from the hind limbs. The impulse necessary for movement is provided by the hind limbs (Higgins 2012).Almost a hundred years ago in 1928 Dr. Endre Gy. Guoth published a study under the title ”Data for the bone structure and the change of shape of metatarsus in horses”. This fundamental work called my attention to the connection between the work performed and the metatarsus, the morphology of the metatarsus. It is worthwhile to quote literally the author’s finds, most important for our topic, which are still valid and serve as a starting point for us: ”Although it is natural for certain parts of the compacta to be thicker or thinner, the bearing of weights and the work done doubtlessly influence its differentiation and the differences apparent in respect of the thickness of the compacta can be attributed to that.

The shape and structure of the metatarsus depend on the type, the use (trotting horse, galloping horse, jumping horse) and the leg position.” (Guoth 1928).

The metatarsus is such a bone that is intensively exposed to static and dynamic forces. Owing to its size, shape and dense structure it survives for a long time under the most various circumstances after the animal dies and often turns up soundly in a large number of excavations. These facts justify the thorough analysis of the metatarsus, also filling a gap in the detailed, comparative osteometric analysis of the metatarsus bone structure of horses, omitted so far.

Selection and grouping of samples

The sample is a set of metatarsuses originating from wild horses of Pleistocene geological age accidentally found in gravel quarries and from domesticated horses with a life history described by data providers. All the pieces have been collected by us. Each piece examined has been allocated a specimen ID number and the known data of life history were recorded for modern specimens. Based on life history, the metatarsuses were arranged into groups:

- specimens living in a natural way (fossil wild horses)
- domesticated horse not used for work
- mounts
- draught horses
- used as both mounts and draught horses

In the case of fossil bones the life history data, important for the analysis, were compiled indirectly, just following logic. It is a basic assumption that the individuals of wild horse species lived in a natural way in natural environment. In the case of these samples the following information allows creating amore detailed picture:

1.) the site
2.) the geological age of the find
3.) the preservation status of the find
4.) the residue accumulated in the medullar cavity indicates the closer environment of deposition, suitable for the collection of additional data
5.) reconstruction of the wider environment, habitat of that time
6.) distribution of specimens per geological age
7.) behavioural pattern and group dynamics based on the observation of populations living in the wild today (actualism)
8.) recording the external bone measurements

Site: The bulk of the bones appeared from the gravel quarries in Kiskunlacháza and Majosháza. A smaller part comes from the dredging of the Dunaföldvár section of the Danube river bed.

The geological age of finds: The bones found in Kiskunlacháza and Majosháza are of the Pleistocene age. The ones coming from the Danube could be of late Pleistocene or early Holocene age.

The preservation status of the finds: The finds are not abraded, mostly intact. It is quite likely that they got buried in the habitat of the specimen, on site. The possibility of remote redeposition is low, only the transport of the cadaver or the limb from a remote place could be an option. Based on the external sizes of the bones it may be stated that the remains belong to the specimens of the same species.

Reconstruction of the wider environment and habitat of that time: In respect of the detailed reconstruction of the environment and living space that used to be more expansive, it would only be noted in advance that the Hátság was rich in feed and water. The topographic conditions could not represent any special strain for the horses. (Molnár 2015). At the same time, however, in a mountain or desert area finding feed causes a significantly bigger burden. It is intended to describe in detail the environmental reconstruction of the Hátság in that aspect as part of future research.

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Behavioural pattern and group dynamics of horses based on the observation of wild populations of today: Horses living in the wild are arranged in harems on a territorial basis. The size of the territory of a herd is not related to the size of the herd itself, but the carrying capacity of the area. For instance, in New Forest (England) within the Atlantic climatic zone a herd lives in the area of 0.8-10.2 km^2, in boreal forest in 2.6-14.4 km^2,in arid regions in 3-78 km^2. In some areas horses survive in most of the year, while elsewhere they follow seasonal migrations. A harem is a closed herd consisting of mares, foals, and one or maybe two stallions. The stallion protects the harem, thus the mares have more time to feed and the foals have better chances to survive. The closely-knit herd functions properly only under favourable environmental conditions, i.e. sufficient quantity and quality of feed, and access to a watering place. If there is a scarce number of drinking places located at great distances a different type of herd is formed. It is not feasible for the members of the harem to stay together due to their different physiological needs. For non-lactating mares and foals over 3 months it is sufficient to drink every 3-5 days. Lactating mares and foals younger than 3 months need to drink every day. Lactating mares and their foals permanently stay close to the watering places, while the rest look for better feeding in remote areas. Both mare groups contain specimen with a foal bearing potential and in oestrus. The stallion remains at the place forming the basis of the territory, i.e. close to the water, for most of the year, with the young foal mares. The mare will have a foal bearing potential first on the 9th day after foaling, the stallion will mate with them. Here they also mate with those mares that visit the watering places less often and that are able to receive them. This type of harem is a lot looser and unstable than those living in a favourable environment. When male foals become sexually mature, they are ”ostracized” by the herd, and to be integrated into a so-called bachelor group. Female foals remain in the family (Duncan & Vigne 1979).

Horses are living in the wildlife in a 24-hour rhythm. While feeding and looking for a watering place they may as well cover distances of several 10 kms. They feed in 5-7 longer grazing periods per day, including overnight, and they spend approximately 16 hours a day grazing. Their diet is diverse. They like different types of grass, but they also chew on bushes and trees, eat water plants. During the vegetation period they choose open meadows of the best possible quality. They also get along under unfavourable circumstances, with scarce food and little water. In the winter the daily grazing period is shorter than in the summer, and in the summer overnight grazing is general, while it hardly ever occurs in the winter. Mares spend more time grazing than stallions. The selection of food is typical for all groups. The herd grazing several kilometres from the watering place generally visits the water and drinks once a day. The horses living close to the watering place drink several times a day. If the source of water is limited, the dominant animals drink first. The herd would leave the watering place after all the specimens have already drunk. Under extreme circumstances they can go without drinking for 3-5 days. They sleep in poliphases, in several parts. According to observations, they spend approx. 40% of the 24-hour cycle with resting, mostly at night. They stand 2/3 of the resting period, and in 1/3 they lie down. In cold weather the time spent with lying is shorter. The mares in their reproduction phase (pregnant, lactating) rest more while standing than the stallions and the ”sterile” mares (Duncan & Vigne 1979).

The mortality rate is the highest at the early phase of life and in old age. Specimens who reach the age of one year have good chances to survive until their adult age and from the age of 10 years mortality is skyrocketing. The expected life span is longer in the case of stallions than in the case of mares due to the risks of pregnancy, foaling and foal rearing. In smaller families the number of foals is disproportionately low, and the survival rate of juvenile specimens is also low. In the Assateague Island in the population of wild ponies during an observation period of 8 years, the reproduction rate and the survival rate of foals were as follows. The foaling rate was 57.1%, and 88.3% $\pm$ 3.6% of the foals survived until their first year. 53% of the foals were mares. Mares younger than 3 years did not foal. 23% of the 3-year-old mares, 46% of the 4-year-old mares, 53% of the 5-year-old mares, and 69% of the 6-year-old mares foaled. 18-25% of the generation growing up fell prey to predators (Keiper & Houpt 1984). Based on the observations, 57 foals fall on theoretical 100 mares, from which approximately 50 new-born will stay alive, appr. 12 foals become the prey of predators, 38 live long enough to be 1 year old, and the distribution of their gender is 20 mares, 18 stallions (Mills et al. 2005).

The ancient wild horses whose remains we examined lived in a natural way, under natural circumstances according to a behavioural pattern and population dynamics typical to the species, in flood plains along rivers, in the environment of smaller oxbow lakes, alluvial fan, narrower valleys, open grassy areas, and mixed deciduous and coniferous alluvial forests. There were no considerable differences in altitude in their habitat, feed and drinking water could be available in sufficient quantity, which was affected by the change of seasons.

Distribution of specimens per age: One bone find originates from a juvenile animal, two from subadult, two from young adult, and the remaining 40 samples from different adult specimens of unidentifiable age.

Data of the life history of recent horses: In the case of domestic horses the following life history data have been published. We defined their age based on their teeth as well. The course of life of several of them was personally known because of the treatments.

1.) age
2.) sex
3.) breed
4.) manner of use
5.) rearing method
6.) the health status of the limbs
7.) place of rearing
8.) number of foalings in females

The analysis method

Intact phase: The external size of the bone is recorded by using the method common in archeozoology (measurement unit mm, the measuring instrument is calliper (von den Driesch 1976: 92–93):

Values measured:

1.) largest length: GL (by von den Driesch 1976)
2.) proximal epiphysis width: Bp (by von den Driesch 1976)
3.) proximal epiphysis depth: Dp (by von den Driesch 1976)
4.) the circumference of the diaphysis at the heights of the foramen nutricium: Dc
5.) diaphysis width at the heights of the foramen nutricium: Diw
6.) diaphysis depth at the heights of the foramen nutricium: Did
7.) distalepiphysis width: Bd (by von den Driesch 1976)
8.) distal epiphysis depth: Dd (by von den Driesch 1976

Values calculated:

1.) slenderness index:

(Diw/GL)*100

2.) newly introduced is the smallest width and depth ratio of the diaphysis, which is the geometric index:

G=Diw/Did

3.) wither height according to Vitt expressed in cm:

(GL*5.23)/10

Analysis of the X-ray image of metatarsus III for establishing bone structure: Creating a bidirectional X-ray image of the intact bone in the following orientations.

- Dorso-plantar view: the bone lies on the cassette on its plantar surface, leans on the crista articularis, the area of the distal epiphyses is horizontal (**Fig. 5.**).
- Latero-medial view: the metatarsus lies on the cassette on its medial side, the epicondylus lateralis radii is horizontal (**Fig. 6.**).
- Recording of the section in transverse sectional plane from the direction of the joint surface. (Part of the invasive phase, **Fig 7.**).
- With the values of 60 kV and 16 mAs the images were taken with the FUJIFILM VisioVIEW digital system.

In the evaluation, on the X-ray image we can view the width dimensions, alterations, radiodensity of the cortex, the existence or lack of the growth zones (information for establishing the age group), the spaciousness and trip of the medullar cavity, the positioning and the development of the bone spicules. The bone spicules in all cases are adjusted to the load conditions. In the parts exposed to bigger load there are more bone spicules and these are more densely positioned, they are positioned in the direction of the force. In the transverse sectional recording we can get information about the positioning of the change in the width of the compacta and sclerotisation is also apparent.

Invasive phase: preparation of the metatarsus for measurement.

- The structure of the metatarsus is most typically characterising the specimen in the zone of f.n. (*foramen nutricium*) height± 5 mm, the f.n. sets the place of the section (**Figs. 5-6.**).
- The section is prepared and refined in the heights of the f.n. in a perpendicular plane to the longitudinal axis of the bone.

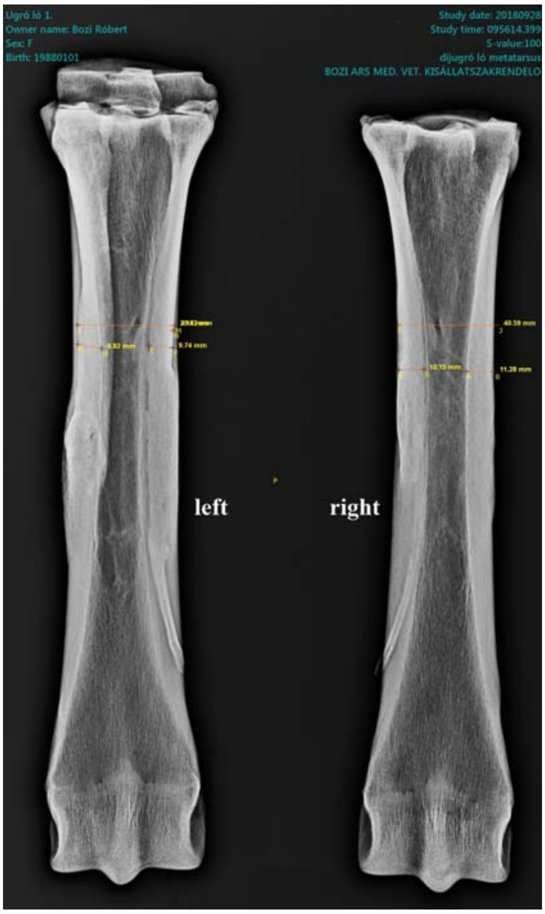

Fig. 5.: Dorso-plantar view

5. ábra: Dorso-plantaris nézet

Fig. 6.: Latero-medial view

6. ábra: Latero-mediális nézet

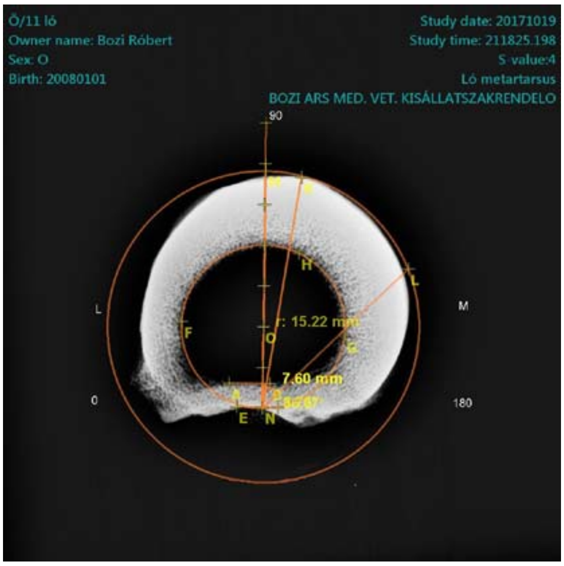

Fig. 7.: Transverse section (ö/11, 8 years old, castrated, used a carriage, r mt III)

7. ábra: Haránt metszet (ö/11., 8 éves herélt fogatló, j mt. III.)

- Determining the plantar plane. The plantar surface of the metatarsus shows proximal variability from the *foramen nutricium*, therefore the plantar external border line of the section is quite variable, too. The diverse alignment makes it difficult to determine the plane of the rear panel. However, it is a requirement that the plane of the rear panel be determined in a standard and repeatable manner. The correct definition requires a simple aid. We had tools cut using a water jet from 2 mm stainless steel plates in the shape of large printed letter T, whose shorter leg is 40 mm long, 10 mm wide, and longer leg is 40-60 mm long and 15 mm wide. The size variants allow the selection of the properly corresponding aid and its adjusting to the bone, and we fixed it with plasticine. The aid must be placed in the area between the metatarsus II and IV that its long leg would cover the almost trapezoid area similar to fingertip imprint, but only that, and its short leg should be in the place of the surface of the section, be adjusted there without tilting, and this can be solved the best way with a proper-size device on a glass plate. (**Fig. 8.**).

Fig. 8.: Setting the plane of the rear panel

8. ábra: A hátfal síkjának kijelölése

- On fossil bones the polished surface often demonstrates the history of earlier bone development due to its ”growth ring” structure of various shades of colour (**Fig. 9.**).

- The section is painted with white tempera paint, and the edges are cleaned from the paint before digitalization (omitting to disbursement that may cause a measurement error), then we scan it. A surface painted white makes the measurement easier, the perimeters are well visible; the watercolour is easy to wash and would not stay (**Fig. 10.**).

Steps of the measurement: The measurement of the width of the metatarsus bone cortex is executed on a transverse section at the height of the *foramen nutricium*, in a 0°-180° angular range in 5° curve resolution, on the image enlarged at least twice.

Determining the special points - 0°, 90°, 180°: The basic line is construed, which is parallel to the line bordering the transverse section of the plane of the rear panel form the outside, and the cortex adjusts to the closest point of the curve bordering it from the direction of the medullary cavity. It is necessary for setting the location of the reference points: 0°, 90°, and 180°. Laterally 0°, medially 180° are set on those points where it intersects the curve bordering the cortex from the outside. For setting 90° a triangle is constructed in the projection of the medullary cavity where its apexes are adjusted to the curve bordering the cortex from the direction of the projection of the medullar cavity, at remote points. The circum-circle is constructed. A perpendicular line is drawn from the basic line via the centre of the circle towards the dorsal. Where the half line intersects the perimeter of the cortex external, 90° is there.

Fig. 9.: Natural colour section (ö/17., fossil, Pleistocene period r mt III)

9. ábra: Természetes színű metszet (ö/17., fosszilis, pleisztocén j mt. III.)

Fig. 10.: Painted section (ö/17., fossil, Pleistocene period r mt III)

10. ábra: Festett metszet (ö/17., fosszilis, pleisztocén j mt. III.)

Fig. 11.: Data form the measured section (ö/9., 6 years old, driven in a carriage, in pair, r mt III)

11. ábra: Mért metszet (ö/9., 6 éves, kettes fogatban járt, j mt. III.)

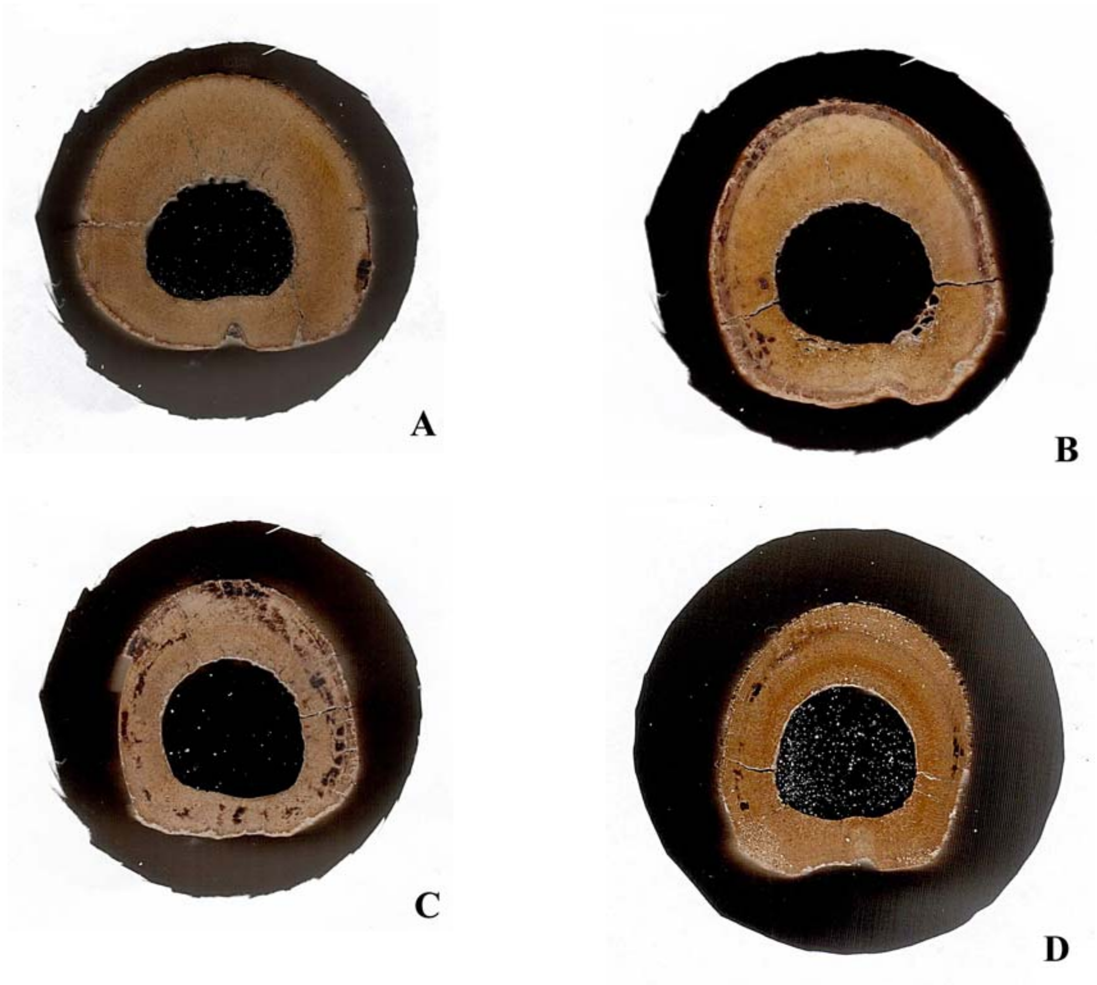

Fig. 12.: Metatarsus III sections from specimens of different age (A: mature, ö/20., fossil, Pleistocene period r mt III, B: young adult, ö/34., fossil, Pleistocene period l mt III, C: subadult, ö/31., fossil, Pleistocene period l mt III, D: juvenile, ö/22., fossil, Pleistocene period r mt III)

12. ábra: Különböző életkorú egyedektől származó mt. III. metszetek (A: maturus, ö/20., fosszilis, pleisztocén j mt. III., B: fiatal adultus, ö/34., fosszilis, pleisztocén b mt. III., C: szubadult, ö/31., fosszilis, pleisztocén b mt. III., D: juvenilis, ö/22., fosszilis, pleisztocén j mt. III.)

- *Measuring the width of lateral, dorsal, and medial cortex.* Knowing the location of the special points we intersect the projection of the transverse section of the cortex between 0-180° by half lines in every 5° angle, where the starting point of the half lines is the starting point of the half line setting the 90°. The intersection of the external bordering line of the cortex and the half lines is the centre of the osculating circle to the line bordering the cortex from the inside at the given degree. The length of the radius of the circle thus constructed is the width of the cortex at the given angle. We measure the lateral, dorsal and medial cortex in the manner described above in every 5° angle. The data set thus received contains 37 elements, and the 37 measuring points represent the changes in the width of the bone cortex (**Fig. 11.**).

Fig. 13.: X-ray image of metatarsus III bones from specimens of different ages
13. ábra: A különböző életkorú egyedektől származó mt. III csontok röntgen képe

- *The maximum width and location of the bone cortex*. We determine the maximum of the cortex width: *Cmax* and its location *Cmaxloc*, marked $\bar{X}$. After the width maximum, if another increase replaces the tendency of decrease, the new maximum and its location must be determined also: $Cmax_n$; $Cmaxloc_n$. If the cortex maximum width covers a bigger curve than 5°, I apply the geometric mean of the angular field for $Cmaxloc_n$

$$G\bar{X}: \sqrt[n]{\bar{X}_1 \times \bar{X}_2 \times \bar{X}_n}\,.$$

- *The width of the plantar bone cortex*. The tarso-metatarsal joint is bent passively, pulling and torsional stress slightly impact the plantar-positioned metatarsus bone cortex matter, this area is bridged by the tendon of the superficial and deep digital flexor muscle, and the short muscle of the third finger. Therefore, here the extent of the hypertrophy derived from environmental impacts is insignificant. The width of the plantar cortex is a good basis of comparison for determining the size of the load the specimen is exposed to. Due to the diversity of the plantar area the width of the cortex must be measured at several points. The arithmetic mean of the measured width values must be calculated:

$$\frac{P_1 + P_2 + P_n}{n}$$

The arithmetic mean of the cortex width of the plantar area $\overline{P}_n$ shows a slight dispersion among the specimens.

- *Load intensity.* Experience shows that the bigger the load is, the bigger the width of the hypertrophied area is. The value of the $\frac{C_{max}}{\overline{P}_n}$ ratio increases by the extent of the load. The ratio of the maximum width of the cortex and the average width of the plantar cortex is the least exposed to load provides information about the extent of the specimen's environmental load. The extent of the load is influenced by the body mass.
- *Load durability*. The angle field of the 3% deviation of the largest width: $Cmax_{97\text{-}100\%}loc$, marked: ***Y*** characterises the *Cmax* area of the cortex exposed to hypertrophy deriving from environmental load. The extent of expansion refers to the relative duration of the environmental impact with some restrictions. The durability of the load within a specific tafocenosis may be sorted within groups created based on the extent of the load. The following formula is used for determining the relative duration of the load:

$$\left(\frac{C_{max}}{\overline{P}_n}\sin\gamma\right)x10$$

This formula takes into consideration the intensity of the load and the expansion of the hypertrophied area. Within groups of similar load intensity the calculated value will be higher in case of more durable load. This conclusion applies to adult specimens.

- *Load type*. The load type is characterised jointly by the location of the *Cmaxloc* and the intensity of load $\frac{C_{max}}{\overline{P}_n}$.
- *Data characterising the life history*. The data set characterising the entire life history may be linked as follows in the language of mathematics:

$$\left(\frac{Cmax}{\overline{P}_n} \times \frac{1}{\sin Y}\right) \times \cos X^2$$

The values thus received show massive deviation due to several variables independent from one another. The currently examined material is not suitable for determining the type of load, due to small sample size.

Evaluation of results

In interpreting the results, the following is to be taken into consideration:

- Rare occasional work does not leave a mark on the bone structure of the metatarsus III (see Inv. nr.: ö/10 rec. riding pony, Inv. nr.: ö/4 rec. draught horse).
- Among the irregular leg positions, the varus position and cow hocks modify the cortex structure and the greatest width of the cortex develops at a place different from regular.
- Pathologic phenomena must be distinguished from the physiological ones.

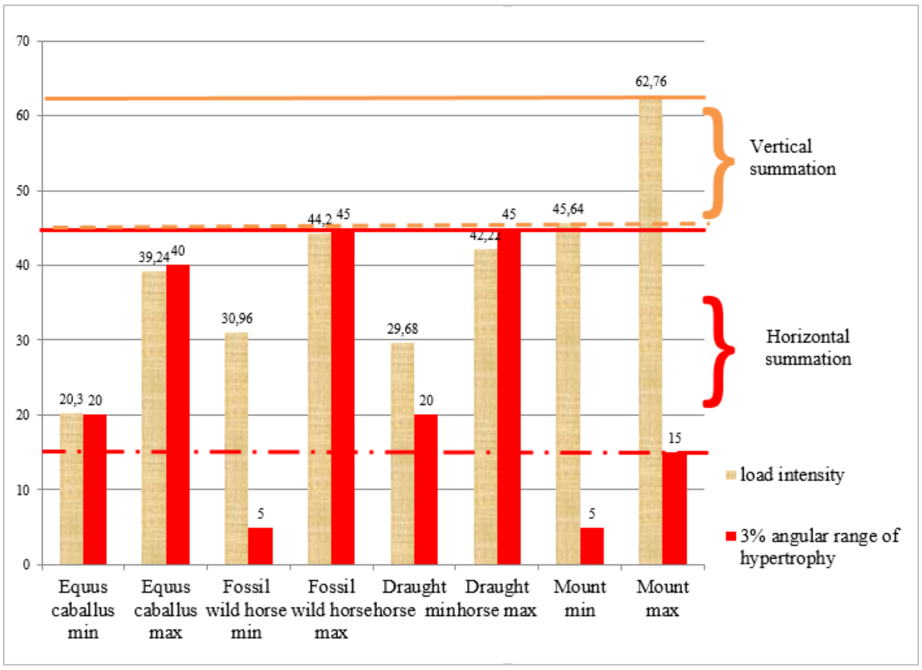

Fig. 14.:

Vertical and horizontal summation

14. ábra:

A vertikális és horizontális összegzés

- Juvenile and subadult specimens represent a separate category in the interpretation of the results. In our case, the pace of ontogenesis and ethological reasons modify the environmental impact. This is shown by the comparison of the bone structure of specimens in different age groups and living in similar exposure to the environment (**Figs. 12-13.**).
- The hypertrophy permanent for life appears in old individuals not having worked for a longer period.
- The phenomenon of summation: the hypertrophy evolving in case of a natural lifestyle and deriving from work both develop on the bone. This has to be taken into consideration when interpreting the phenomena (**Fig. 14.**).

Comparative evaluation of the life history groups.

The analysed parameters that can be evaluated may be classified into two groups:

- parameters with the same meaning attached to them in all of the groups: *Cmax*, $\frac{Cmax}{\bar{P}_n}$,

$$\left(\frac{Cmax}{\bar{P}_n} \times \sin Y\right) \times 10$$

- group-specific parameters, jointly: *Cmaxloc*, $\frac{Cmax}{\bar{P}_n}$.

  The biggest cortex width, load intensity and load durability may be evaluated the same way in all life history groups. The location of the maximum cortex width and the extent of the load together are key to the type of load.

The location of the largest cortex width per life history groups (**Figs. 15-18.**):

- specimens having lived in a natural way (fossil wild horse) 86°-88°: 2 pcs.; 4.55%,90°-110°: 37 pcs.; 84.1%, 112°-117°32’: 5 pcs. 11.35%, total of 44 pcs. (**Fig. 15.**)
- domestic horse which did not work 95°-107°28’, total of 7 pcs. 100%. (**Fig. 16.**)
- mounts 100°-110° 4 pcs. 80%; 115° 1 pcs. 20%; total of 5 pcs. (**Fig. 17.**)
- draught horses 117°28’ 1 pcs. 20%; 125°-127° 4 pcs. 80%; total of 5 pcs. (**Fig. 18.**)
- used as both mounts and draught horses

Knowing the location of the largest cortex width an opinion can be formed about the leg position.

1.) *Cmaxloc*<88°: varus position

2.) *Cmaxloc*=90°-110°: regular leg position

3.) *Cmaxloc*≥112°-118°: open leg position, cow-hocked position

According to environmental load, two groups can be distinguished.

1.) The wild and non-working domestic horses, and mounts form one group: *Cmaxloc*: 86°-117°32’.

2.) In the case of draught horses 2 maximum values can be found, $Cmaxloc_1$: natural load, $Cmaxloc_2$: work hypertrophy 118°-127°.

The $\frac{Cmax}{\bar{P}_n}$ values of examined specimens of the wild species vary between 2.210-1.548. (**Fig. 19.**).

- Higher load value: 2.010-2.210, 14 samples, 31.80%.
- Average load: 1.992-1.712, 22 samples, 50%.
- Low load: 1.685-1.548, 8 samples 18, 20%.

The $\frac{Cmax}{\bar{P}_n}$ values of domesticated specimens not working are as follows:

- 0-day specimen not loaded at all: 1.015.
- 4-weeks old, intensively growing specimen with hardly any load: 1.327.
- specimen with average load: 1.533-1.962.

Owing to the bone structure the starting value of the load is around 1, and due to quick development, this value is spectacularly growing, then the pace of broadening slows down. The load values of domestic subadult, adult specimens are within the range of the load value of wild horses and belong into the low and average load categories.

Age-specific characteristics. The low load intensity value $\frac{Cmax}{\bar{P}_n}$ and large $Cmax_{97\text{-}100\%}loc$ angular field characterise the juvenile specimen together. The ***Y*** value shows an inconsistent picture due to the uneven development. The stallion’s development intensity is higher and the period of growing is longer than in the case of a mare.

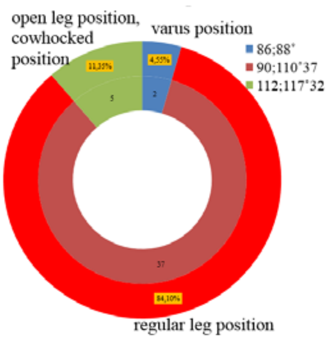

Fig. 15.: Fossil wild horse Cmaxloc distribution

15. ábra: Fosszilis vad ló Cmaxloc megoszlása

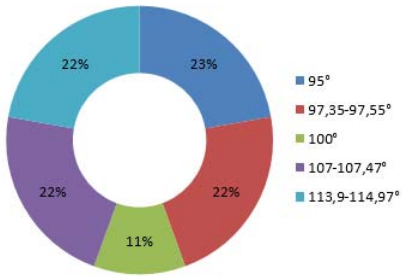

Fig. 16.: Domestic horse, non-working Cmaxloc distribution

16. ábra: *Equus caballus*, munkát nem végzett Cmac loc megoszlása

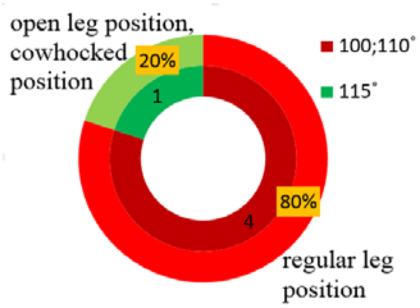

Fig. 17.: Mounts, Cmaxloc distribution

17. ábra: Hátas ló Cmaxloc megoszlás

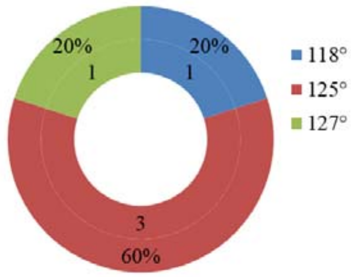

Fig. 18.: Draught horses, work derived hypertrophic Cmaxloc distribution

18. ábra: Fogat ló munka-hipertrófiás Cmaxloc megoszlása

The impact of working. We will have a more complete idea when *Cmaxloc* and the value of $\frac{C_{max}}{\bar{P}_n}$ (load intensity) are interpreted together. In this case the hypertrophy caused by regular working and deriving from natural life-style are separated.

The specimens of wild and non-working domestic horses have been analysed above; below the effects of the various types of work will also be examined.

Mounts: The *Cmaxloc* angular range for mounts, the resultant of static and dynamic forces, was identical to that of the specimens of wild and non-working domestic specimens, as the centre of gravity falls under the vertebral column in all three groups. The $\frac{C_{max}}{\bar{P}_n}$ value of load intensity varies between 2.282-3.138. In all cases it exceeds the load values of the ancient wild species and the non-working domesticated species. In the case of mounts hypertrophy is the joint product of the work done, the natural environmental load, and the leg's conformation. The work performed results in the increase of load intensity at the same place, where the resultant of the natural forces is apparent, and added to it. This is the phenomenon of vertical summation.

Draught horses: In the case of draught horses two cortex hypertrophy maximum values, *Cmaxloc* develop, the first is $Cmaxloc_1$ dorsally, which is the resultant of the natural load and leg position $\boldsymbol{X_1}$, and the own point of gravity is under the vertebral column. The second is $Cmaxloc_2$ appears medially in the angular range between 118°-127°, which is the result of work hypertrophy, the point of gravity of the tow is behind the horse. The two types of load are not built on each other. Therefore, the load intensity value $\frac{C_{max}}{\bar{P}_n}$ of draught horses varies between 1.484-2.133, and is within the load value range of wild and domesticated, not working specimens. Naturally, this value may be higher, subject to the work performed. The cortex width maximum $Cmaxloc_{97\text{-}100\%}$ angular range, there growth $\boldsymbol{Y}$ may overlap, may be more excessive than justified by the duration of the load. Here the phenomenon of horizontal summation can be observed (**Figs. 14., 20.**).

Sign of gestation: In the case of the only riding mare whose foaling has been proven, and on 4 pcs. of fossil bones between 145° and 155° additional cortex widening developed. Its span is 5° angular range. It is probably caused by the carrying of a pregnancy. This possibility is reinforced by the fact that this phenomenon is not apparent for a single juvenile, subadult, male or castrated specimen. The anatomical circumstances also justify its development. The suspensory ligament of the uterus, the mesometrium, is attached to the dorso-lateral abdominal wall and pelvic floor, the lumbar muscle. The round ligament of the uterus, the *lig. teres uteri*, attaches to the internal *anulus inguinalis* (Fehér 1980, 445). There is a substantial possibility for the uterus to move. The point of gravity of the growing foal moves deep and backwards when the horse is under stepping. Studying a larger number of individuals is necessary to have to be able to completely prove the causal relation**.**

Interpretation of the geometric index

Finally, at least briefly, we have to mention the feature obtained in the intact phase, the ratio of the smallest width and depth of the metatarsus diaphysis, i.e. the geometric index. The value of its use is limited. On this basis, it is not possible to form a firm opinion on the life history of a specimen. The value around 1 refers to a natural way of life, the value lower than one suggests riding work and the value higher than one suggests the possibility of draught exploitation.

Conclusions that can be drawn from the analysis of the permanent marks of working and way of life on the horses' metatarsus

The above-described method provides a possibility to establish the main features of a specific specimen with a likeliness of 80-85%.The data of the horses' life history help the interpretation of archaeological phenomena. They inform about the earliest appearance of the various manners of use and broaden our view on the farming methods, livestock breeding work, the movement of the groups of people and the social layers.

– The maximum cortex width of the specimens of wild horses and the non-working domestic specimens is between 86° and 117°28ʹ in all cases, and the load intensity hardly exceeds the value of 2.13.

– The highest cortex width values of mounts fall in the angular range of wild and non-working horses. The load intensity values are higher than wild and non-working horses.

– The highest cortex width values of draught horses fall into the angular range of 118°-127° and their load intensity values are not outstanding.

– The load intensity values provide us with information about the external circumstances the animal had to withstand. In a specific tafoconosis, in a collection of archaeological phenomena, within the groups created based on load intensity and manner of use, it is also possible to relative period of use, according to the 3% expansion of hypertrophy.

– We can also draw conclusions about the reproduction of the animals from the existing or lacking additional cortex widening between 145°-155°. The relevant finds need further confirmation statistically.

– Two anomalous leg positions, i.e. the varus position and cow hocks, make a mark on the metatarsus structure. *Cmaxloc* <88° positioned on the latero-dorsal suggests varus position, while *Cmaxloc* ≥ 112°-118° open position (cow hocks). The accumulation or lack of abnormal leg positions within one taphocoenosis may as well be the sign of breeding, should we have a sufficiently large series of bones to analyse. In the examined fossil wild horse remains (natural reproduction community) 4.55% has varus while 11.35% open leg position. (**Fig. 15.**.)

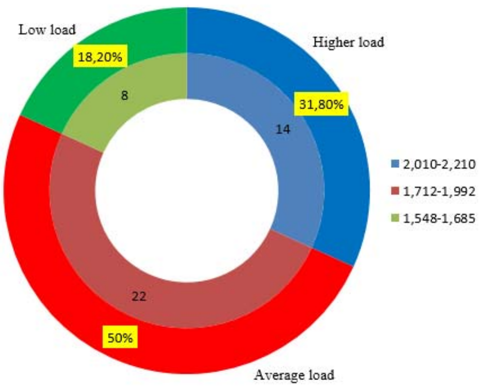

Fig. 19.: Fossil wild horse load intensity distribution

19. ábra: Fosszilis vad ló terhelés intenzitásának megoszlása

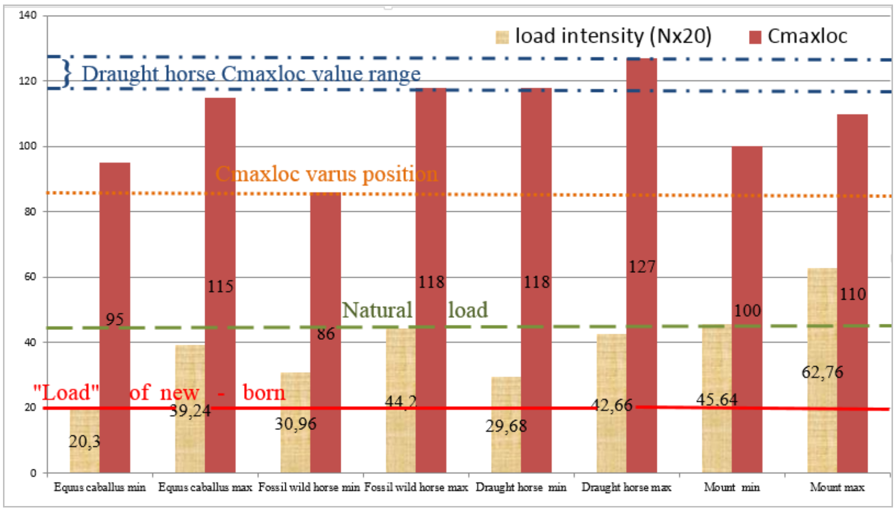

Fig. 20.:

Load intensity and Cmaxloc values of life history groups

20. ábra:

Az élettörténeti csoportok terhelés intenzitása és Cmaxloc értékei

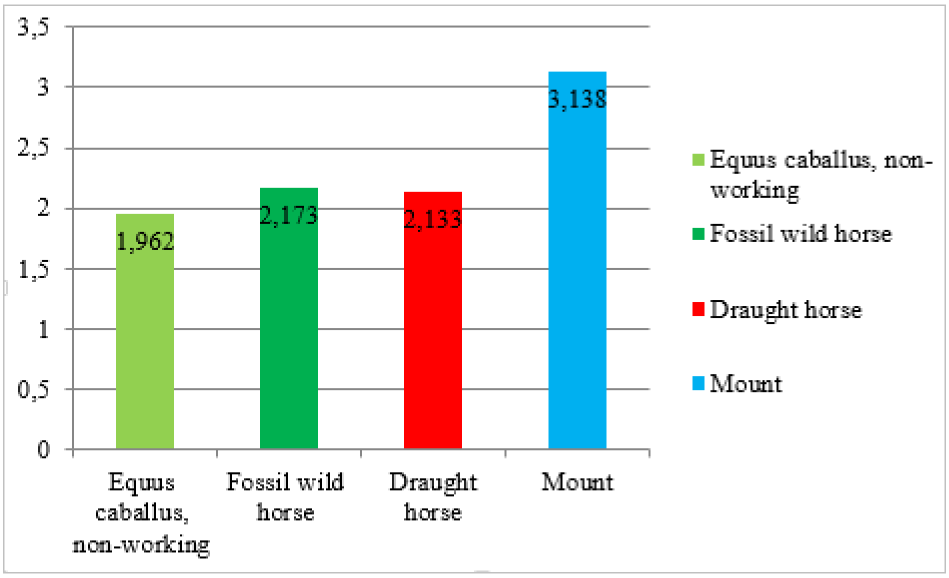

Fig. 21.:

Maximum of load intensity

21. ábra:

A terhelés intenzitásának maximuma

The compiled database must be continuously extended. The more we know the more certain our interpretation can be. In order to analyse other manners of use, e.g. pack-horses, draught horses used in transport or tillage, it is necessary to further refine and control the method. Animals used in various sports must also be examined: horses used for show jumping, military horse, horses in driven dressage, trotters, etc., to see whether there is a significant difference in their bone structure. Furthermore, the analyses have to be extended to other animal species as well, such as donkeys, mules/hinnies, cattle, camels, etc.

The analysis of the permanent marks of working and the way of life on the metatarsus of horses of archaeological age

Dombóvár-Tesco, tomb DTQ83: The horse excavated with saddle remains and a bit in its mouth was a typical mount according to the information collected based on the gracile bone remains, most useful in reconstructing the animal's life history (metacarpus III slenderness index 14.23, metatarsus III slenderness index: 12.02, the metacarpus/metatarsus GL ratio is 0.855. Considered to be tall in its own age, its withers height calculated from the metatarsus III was 146.18 cm (Vitt 1952). The skull is narrow, high, short, the profile is pronounced, the muzzle runs straight. Based on its teeth, it is a male of around 6-7 years of age. The incisors show an irregular abrasion suggesting cribbing. On the left *condilus occipitalis* an osteophyte of the size of a small bean is apparent, and on the joint surfaces of the atlas a corresponding dimple, with the traces of an inflammatory reaction around it. The external sizes and the calculated values of the metatarsus III analysed with the method described and the measured and calculated values of the cortex are included in the tables attached (**Table 9.**). The maximum width of metatarsus III cortex is located at 90°, which indicates regular leg position.

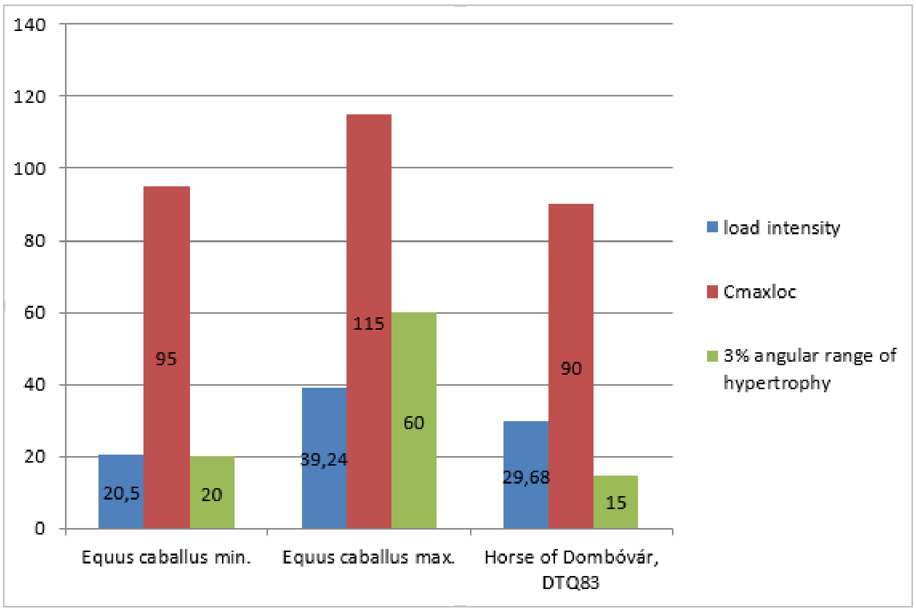

Fig. 22.:

Characteristic bone structure values of non-working horse and the horse of Dombóvár

22. ábra:

A munkára nem fogott és a dombóvári ló jellemző csontszerkezeti értékei

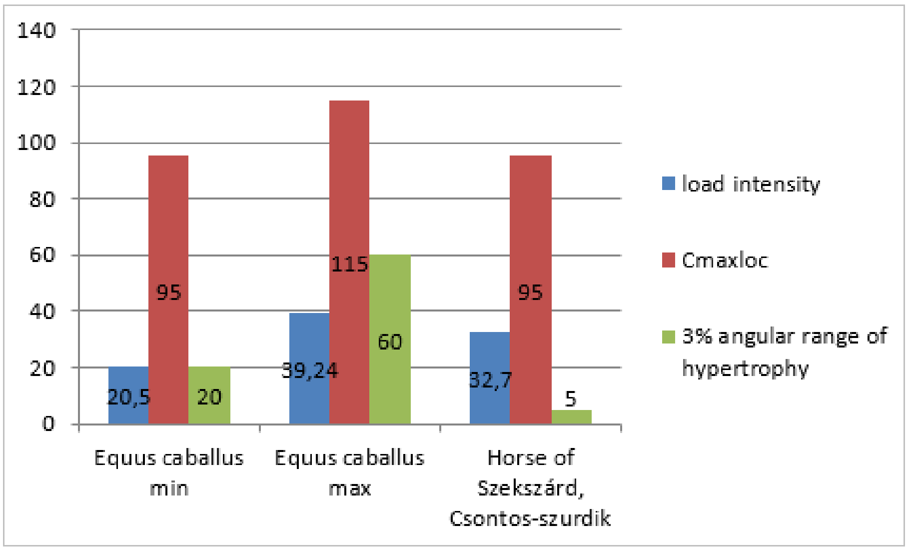

Fig. 23.:

Characteristic bone structure values of non-working horse and the horse found in the Csontos-szurdik

23. ábra:

A munkára nem fogott és a Csontos-szurdikban előkerült ló jellemző csontszerkezeti értékei

Additional width growth is not apparent. The load intensity value is low, and the 3% deviation from the maximum width covers a medium (15°) angular range. The observed phenomenon characterises horses that are not subjected to work (**Fig. 22.**). In light of the results of the database available to us the low load value, and the abrasion of teeth suggesting cribbing, indicate a specimen condemned to boredom (Kardeván 1976; Takács 1994, 155-157., Abb. 7). It was probably kept in a corral or tied down in a stable. The alteration developed on the knob of the nape and the atlas vertebra could significantly restrict the normal use of the animal, for instance it was unsuitable for riding.

Szekszárd, Csontos-szurdik: Among the bones washed out from the side of the embankment we analysed the foot of the left hind leg of a horse and the skull of another specimen. Two metres east of the foot, the skull of the horse lying on his left side and facing east was protruding from the embankment. Its cervical vertebrae were in anatomical order. The embedded position suggested a bowed head. The skull that could be observed only partly belonged to a mare of the age of 15-16 years. Its age was determined based on the seed mark apparent on the chewing surface on the right I3 incisor, the only remaining tooth, and the comparison of the anatomical features and the percentage distribution of the crown, body and root of teeth based on the X-ray images taken of the jaws of a horse of a known age. Based on the image of the incisor the animal is closer to the age of 15 but looking at the premolar- molar teeth it was closer to 16 years of age. It was identified as a mare due to the lack of canines. The high, wide, short skull suggests a small, rough head. Its measurements fall between those of the skulls from the tombs of the German horse-dog double burials described in the Avar period graveyard of Keszthely (Bökönyi 1974, Table 5, Fig. 113, 290-292; Vörös 1999a). Based on its size, this skull is also close to the horse found in the tomb of early Avar period in Békéssámson (Vörös 1998), however, it is smaller than the horses found in the tombs from the Period of the Hungarian Conquest of the Carpathian Basin (Vörös 1999b). All this suggests that the remains of the skull, based on its sizes and structure, can be positioned among the Avar period types, which was subsequently fully confirmed by the results of radiocarbon dating.

The foot bones were found in plantar flexion (in a position of flexed sole), in anatomical connection, closing an angle of 40-50° with the horizontal plane, into the porous, greyish-brown soil of the embankment. Based on the sizes of the metatarsus it belonged to a slender-legged (slenderness index metatarsus III= 12.74), short adult specimen of small to medium withers height (calculated from metatarsus III= 135.45 cm, Vitt 1952). The external sizes and the calculated values of the metatarsus III analysed with the above-described method, and the measured and calculated values of the cortex are included in the tables attached (**Table 10.**). The maximum width of the metatarsus III cortex is located at 95°, and it indicates regular leg position. The 3% deviation from the maximum cortex width covers 5° angular range, the environmental load is of medium extent (1.635) and the value indicating the durability of the load is low (1.425). In light of the results of the database available, the medium intensity of the load measured indicates a grazing life style, and the low value marking the durability of the load assumes death at a young adult age (**Fig. 23., Table 10.**).

Archaeological evaluation of the test results of permanent marks on horses' metatarsus caused by work and way of life

Dombóvár-Tesco, tomb DTQ83: According to its prime age, based on the circumstances of burial, the dog placed near it, the fittings at its back assumed to belong to the saddle, the bit in his mouth, and the burial of the rich person in its proximity so far the most likely idea was that it could have been the favourite mount of a local leader (**Figs. 1-2.**). Practically, based on all the archaeological observations the assumption seems completely logical that the master was buried with his favourite animals, where the only question is whether it was hunts or battles in which they grew so much together that they took their journey into the underworld also together (Boruzs 2013). The remains of horses and dogs, as the persons carrying out the tests put it, show relations with at least one of the deceased people found in the complex and – in addition to serving as companions – they may have been indicators of status in earthly life (Daróczi-Szabó & Bartosiewicz 2018, 251).The data measured and received by using the now presented analysis method, however, rule out this concept fundamentally, even despite the archaeological observations. The load intensity value calculated based on the measurements is low, and the 3% deviation from the maximum width covers a medium (15°) angular range, which characterises horses not subject to work – that is, it does not confirm the ideas implying a favourite ridden a lot (**Fig. 22., Table 9.**). Due to the alteration developed on the knob of the nape and the atlas vertebrae, this specimen was not suitable for riding and it is quite likely that his head position was abnormal, moved to the side. At the same time, the saddle remains, and the bit in its mouth are highly likely to be meant to send the message to the participants of the funeral–and not only to the archaeologist – that his horse and dog accompanied the master in his long way. However, based on the analysis results of the method now presented, this picture can be made significantly more sophisticated and put into a new perspective.

In tomb DTQ83 a saddled, but with low utilitarian value horse was placed, which shows that the reason why it was buried was not a strong bond - should it be the case the actually used animal would have been buried next to its master. The appearance for the community of killing the horse and putting it into the grave was important, which is proven by its being all harnessed –the present results of the analysis together with the revaluated archaeological observations reflect not the burial of a battle mount, but adherence to significant elements of a scheme of habits (for which killing and harnessing a less valuable animal may have been sufficient). In this context, the historic connections of the Dombóvár late Roman burial with horses and its parallel in Mágocs are seen from a new perspective (Boruzs & Szabó 2018, 206-208; Gábor 1998, 113, 116). In both cases the measurable results of the osteometric tests, complementing earlier observations and assessments of excavations related to burials with horses which is seen as unusual in the area of the province, cast a totally different light on the explanations assumed based on the data available so far. The phenomena and aspects that were less considered previously in the archaeological-historic assessments are given more emphasis now, which, all in all, call attention to the appearance of the custom system of a foreign population in the late Roman era.

Szekszárd, Csontos-szurdik: the data of the radiocarbon analyses verified that these dated back to the Avar period, assumed earlier based on the size of the bones and the values - likely to be limited to the second half of the seventh century - at the same time refer to one of the most exciting period of the Avar times. The archaeological data refer to the transformation of the Avar society that was far from being peaceful at that time and indicate that around 670 new ethnic groups moved into the Carpathian basin and fought internal wars (**Fig. 4.**). The position, mass and angle of the bones in the loess wall, reflect, by all means, a violent action. The angle of the joints observed indicate that rigor mortis did not set in the cadavers yet. Generally, horses are put into the graves with legs pulled under them, but here they were lying on their sides rather indicating that these were carcasses, distended, and released from rigor. The snails indicating waterflows suggest that a natural hollow was used to clear the decomposing carcasses that were still in one piece (Bozi & Szabó 2017, 1131). The bones found in anatomical order also tell us that the decomposing dead bodies were covered by dirt and the body parts were not carried away by the animals. As there were human skeletons among the carcasses it seems that they were not buried by the members of their own community — they would have buried their fellows separately. This could also suggest that the loess embankment hides the traces of a battle, and in this case it would be understandable that people were thrown into the hole together with the horses, as the winner at the end had everything cleaned up indiscriminately and ordered the area to be completely cleared. However, according to the data of the examined metatarsus III the environmental load is of medium extent (1.635), the value indicating the durability of the load was low (1.425), which, all in all, suggests a grazing way of life and death as a young adult, which contradicts the theory of a battle. This means that the samples available from this site are bones of young, non-working and also of old animals and do not belong to horses used in battles or for riding (**Fig. 23., Table 1.**). On top of that, these bones lay in the embankment mixed with the remains of sheep, which is completely alien to a battlefield.

Based on the osteometric test of the samples collected from the Csontos-szurdik site, Szekszárd, the concept of a carcass pit used related to an epidemic or the putative battle mentioned in folk tradition can be ruled out. The results emerging so far all in all rather suggest that the archaeological site, and its bones mixed with the nearly Avar-period settlement, preserved in a unique way the traces of the internal conflicts with newcomers just between the early and late Avar period targeted at the acquisition of the territory, who massacred the people and the animals of an aul indiscriminately, perhaps for deterrence.

The test results of the horse metatarsi collected from the two sites analysed with the above described osteometric method and presented herein as an example significantly contributed in both cases to the clarification of the archaeological-historic connection. Naturally, the test results in themselves are not suitable for answering historical questions. However, as it is indicated by the two case studies, presented as an example of the possibility of archaeological application, the observations and parallels of excavations and the results of previous examinations complemented with the data of the new method may help develop a more nuanced, or sometimes completely new, interpretation of the archaeological-historic connections. The case of the horse from Dombóvár is especially enlightening, which, based on the traditional evaluation of archaeological observations, was thought to be so far a mount buried with its master. The measurable results of the osteometric tests, however, called attention to the appearance of the habits of a newly arrived population in the late Roman period, putting the observations of earlier excavations into a new historic context. Also, in the case of the Csontos-szurdik we managed to determine the age and nature of the site even without an archaeological excavation. These two cases well reflect that the osteometric method demonstrated for the examination of the metatarsus of horses may be an important and useful supplement to archaeological research. The recent results clearly indicate that it would be worthwhile and efficient to repeat the examination and evaluation of such old and well-known finds as, for instance, the horses of the Kurgans of Arzhan and Pazyryk (Bourova 2004; Chugunov et al. 2003; Vitt 1952), and the horses from the time of the Period of the Hungarian Conquest (Matolcsi 1976, 206-209).

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Tables 1-10. for the current paper are provided in the ***Appendix.***

References

BORUZS, K. & SZABÓ, G. (2018): Late Roman Graves in Dombóvár. In: BARTUS, D. & BORUZS, K. eds., *FIRKáK IV. Proceedings of the Conference for Young Researchers of Roman Age.* ELTE Régészettudományi Intézet, Budapest, 197–242.

BORUZS, K. (2013): Harcos vagy vadász? Egy késő római fegyveres sír a Konda-patak völgyében. In: KRISTON VIZI, J. ed., *Dél-Dunántúli dolgozatok. Tanulmányok Dr. Szőke Sándor emlékére.* Dombóvár, 20–30.

BOZI, R. & SZABÓ, G. (2017): A Csontos-szurdik rejtélye: avar kori villongások. *Élet és Tudomány* **LXXII/ 36** 1129–1131.

BOUROVA N. (2004): Horse Remains from the Arzhan-1 and Arzhan-2 Scythian Monuments. In: MARIAN SCOTT E., ALEKSEEV A.Y., ZAITSEVA G. eds., Impact of the Environment on Human Migration in Eurasia. *NATO Science Series: IV: Earth and Environmental Sciences* **42** Springer, 323–332.

BÖKÖNYI, S. (1974): *History of Domestic Mammals in Central and Eastern Europe.* Budapest, Akadémiai Kiadó, Budapest. p. 597.

CHUGUNOV, K., PARZINGER, H. & NAGLER, A. (2003): Der skythische Fürstengrabhügel von Arzhan 2 in Tuva. Vorbericht der russisch-deutschen Ausgrabungen 2000-2002. *Eurasia Antiqua* **9** 113–162.

DARÓCZI-SZABÓ, M & BARTOSIEWICZ, L. (2018): Horse-dog burials from preventive excavations at Dombóvár TESCO. In: BARTUS, D. & BORUZS, K. eds., *FIRKáK IV. Proceedings of the Conference for Young Researchers of Roman Age.* ELTE Régészettudományi Intézet, Budapest, 243–255.

DRIESCH, A. von den (1976): *A guide to the measurement of animal bones from archaeological sites*. Peabody Museum Bulletin 1, Peabody Museum of Archaeology and Ethnology Harvard University. p. 136.

DUNCAN P. & VIGNE N. (1979): The effects of group size in horses on the rate of attacks by blood-sucking flies. *Animal Behaviour* **27** 734–735.

FEHÉR, Gy. (1980): *A háziállatok funkcionális anatómiája I.* Mezőgazdasági Kiadó, Budapest. p. 244.

GÁBOR, O. (1998): Későantik sírok Mágocson. *Janus Pannonius Múzeum Évkönyve* **43** 113–130.

GUOTH, Gy. E. (1928): Adatok a lovak lábközépcsontjának csontszerkezetéhez és alak-változásaihoz. *Közlemények az összehasonlító élet- és kórtan köréből* **XXII** 110–126.

HIGGINS, G. (2015): *A ló mozgásának biomecha-nikája.* Mezőgazda Kiadó, Budapest. p. 150.

KARDEVÁN, A. (1976): *A háziállatok kórbonctana.* Mezőgazdasági Kiadó, Budapest. p. 268.

KEIPER, R. & HOUPT, K. (1984): Refuge-seeking and pest avoidance by feral horses in desert and island environments. *Applied Animal Ethology* **9** 111–120.

KOVÁCH, A. (1922): A szekszárdi „Csonthegy" titka. *Tolnamegyei Újság* **4/53** 2.

MATOLCSI, J. (1976): Shaman horse in a grave from the Period of the Hungarian Conquest at Izsák–Balázspuszta. *Cumania* **IV** 191–223.

MOLNÁR, B. (2015): *A Kiskunsági Nemzeti Park földtana és vízföldtana.* JATEPress, Szeged. p. 523.

MILLS, D. S. & MCDONNELL, S. M. eds., (2005): *The Domestic Horse: The Origins, Development and Management of Its Behaviour.* University of Pennsylvania School of Veterinary Medicine, USA. p. 264.

SZABÓ, G. (2017): Odakozmált a bableves?: étkezési szokások a késő-középkori Dél-Dunántúlon. *Élet és Tudomány* **LXXII/50** 1577–1579.

TAKÁCS, I. (1994): Untersuchung der Tierkno-chenfunde aus dem awarenzeitlichen Gräberfeld von Solymár. *Das awarische Corpus – Avar Corpus Füzetek* **1** 149–176.

VITT, V. O. (1952): Лошади пазырыкских курганов. (The horses of the kurgans of Pazyryk) *Советская Археология* **16** 163–205.

VÖRÖS, I. (1998): A békéssámsoni kora avar kori sír lova. *Móra Ferenc Múzeum Évkönyve, Studia Archaeologica* **4** 373 –376.

VÖRÖS, I. (1999a): Germán ló-kutya kettős sírok Keszthely avar kori temetőjében. *Zalai Múzeum* **9** 121–152.

VÖRÖS, I. (1999b): Tengőd-Hékútpusztai honfoglalás kori sírok lovai. *Herman Ottó Múzeum Évkönyve* **37** 301–312.